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(54) **Image correction.**

(57) An apparatus for correcting defects in an image comprises monitoring means (12) for measuring the values of a parameter from each of the picture elements, processing means (14) for calculating a correction signal from the measured values and control means (16) for applying the correction signal to correct the image defects. The final correction may be obtained using a repetitive sequence of applying the correction signal, monitoring its effect and undertaking further adjustment as necessary. Calculation of the correction signal preferably includes multiplying each of two adjacent line or field parameter values (VALUE 1, VALUE 1) by a respective refrence signal (V REF.1, V REF.2) which has a frequency equal to half the frequency of occurrence of the picture elements whose values are being multiplied, the reference signals (V REF. 1, V REF. 2) being in anti-phase with each other, and summing the multipliedvalues, whereby calculation of the correction signal includes a smoothed interpolation.

FIG. 3.

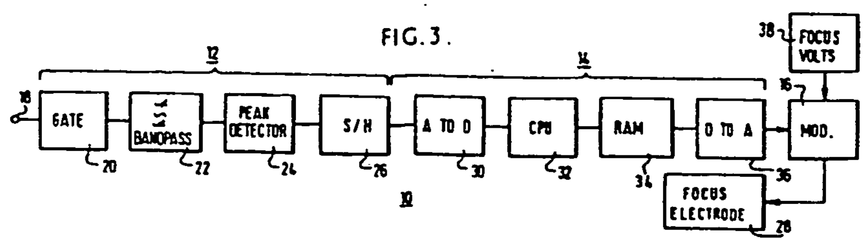

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IMAGE CORRECTION

The present invention relates to image correction and is particularly applicable to image correction in television cameras.

A television camera has an optical system which directs incident radiation onto a camera tube from which electronic signals are obtained. A number of phenomena occur for which correction is required if an acceptable quality television picture is to be produced. The number of phenomena requiring correction is considerably increased for colour television cameras.

Such corrections have in the past been applied by manual adjustment of the relevant controls as determined by their effect upon the final image. Manual adjustment is unreliable, time consuming and generally disadvantageous.

Automatic arrangements have been employed in which a correction signal is applied to the circuitry of the camera or to the electronic signal of the image. These signals are of pretermined form and depend upon the particular phenomena which is being corrected.

Although this technique has been developed so as to introduce complex correction signals, the signals are predetermined in accordance with mainly theorectical considerations.

The corrections applied are calculated for a standard camera tube and therefore any deviation of a tube from the standard will cause a deterioration in performance.

The present invention seeks to mitigate the above disadvantages.

According to a first aspect of the present invention there is provided apparatus for correcting defects in an image having a plurality of picture elements, comprising monitoring means for monitoring the value of a parameter from each of the picture elements, processing means for calculating a correction signal from the parameter values and control means for applying the correction signal to correct the image defects.

According to a second aspect of the present invention, there is provided a method of correcting defects in an image having a plurality of picture elements, comprising measuring the value of a parameter at each of the plurality of picture elements,

calculating a correction signal from the parameter values and applying the correction signal to correct image defects.

One of the above described corrections relates to focus correction.

The image viewed by a television camera is focussed with the camera tube by the generation of an axial magnetic field within the tube in conjunction with an electrostatic field. The magnetic field is set up by passing a current through a magnetic coil, referred to as a yoke, and an electrostatic field is set up by applying a voltage to a focussing electrode. Due to certain well known phenomena the electronic image produced by a camera tube corresponds to a curved object plane and consequently the camera tube image of a flat object is not uniformly focussed. It is known to apply a correction signal to the camera tube electrostatic field in order to compensate for this lack of uniformity of focus. However, conventional correction signals are derived from mainly theoretical considerations and a standard predetermined correction signal is applied to the camera tube image. The resulting focus correction is frequently less than the optimum focus correction especially since each tube/yoke combination will have a slightly different maximum focus object plane of

electro-beam focus correction.

Consequently a preferred embodiment of the present invention provides focus correction apparatus for an electro-optical tube comprising monitoring means for measuring the optimum focus parameter value at each of a plurality of picture elements, processing means for calculating a correction signal from the measured values and control means for applying the correction signal to correct the focussing of images produced by the electro-optical tube.

An associated embodiment of the present invention provides a method of focus correction for an electro-optical tube comprising the steps of measuring the optimum focus parameter value at each of a plurality of picture elements, calculating a correction signal from the measured values and applying the correction signal to correct the focussing of images produced by the electro-optical tube.

Preferably, for each picture element a preset range of focussing voltages is tested so as to identify the voltage which results in the maximum focus parameter value amplitude. The identified voltage represents the optimum focus for the picture element.

Advantageously, the picture element signal is band pass filtered in order that the high frequency energy from the edge of the picture element is used for determining the maximum signal amplitude.

Where a camera contains a number of camera tubes it is necessary for the tubes to have a common spatial registration. For example, in a colour television camera, it is necessary for the three colour tubes to have a common spatial registration. Such a registration must be optimised in order to avoid blurring of the final image. A similar requirement exists for a colour television tube in which the electron guns require registration with each other.

Consequently, in a further preferred embodiment of the present invention there is provided apparatus for calculating relatively small errors in the spatial registration of an electro-optical tube, comprising a reference generator which generates a plurality of reference picture elements, monitoring means which monitor the picture signals of the tube derived from said reference picture elements, comparator means which compare picture element and reference picture element signals, displacement means which, for each picture element, displaces the picture element in a first direction to a position of relativly large registration

error, as measured by the comparator means, and which displaces the picture element in a direction opposite the first direction to a position of substantially the same relatively large registration error, as measured by the comparator means, and processing means for calculating, from the displacements effected by the displacement means, the position of optimum spatial registration and an error signal representing the initial error in spatial registration of the picture element.

An associated embodiment of the present invention provides a method calculating relatively small errors in the spatial registration of an electro-optical tube comprising the steps of generating a plurality of reference picture elements, monitoring the picture element signals of the tube derived from said reference picture elements, comparing picture element and reference picture element signals, for each picture element displacing the picture element in a first direction to a position of relatively large registration error, displacing the picture element in a direction opposite the first direction to a position of substantially the same relatively large registration error and calculating, from the displacements effected, the position of optimum spatial registration and an error signal representing the intial error in spatial

registration of the picture element.

In an alternative arrangement the displacement occurs in successively smaller steps until a minimum error is reached, in contrast to using displacements in opposite directions.

The invention also provides apparatus for compensating spatial registration errors of an electro-optical tube comprising the above specified apparatus for correcting spatial registration errors together with processing means for calculating a correction signal from the measured picture element error signals and control means for applying the correction signal to compensate images produced by the tube for spatial registration errors of the tube.

Similarly, the invention also provides a method of compensating spatial registration errors of an electro-optical tube comprising the steps of the above specified method of correcting spatial registration errors together with the calculation of a correction signal from the measured picture element error signals and the application of the correction signal to compensate images produced by the tube for errors in the spatial registration of the tube.

The vignetting of images produced by an electro-optical tube and correction thereof is known. Image vignetting is also present in some solid state image producing devices. The problem of vignetting is particularly noticable in images produced by devices such as colour television broadcast cameras. Each of the three colour camera tubes will produce a slightly different vignetting and the final image will exhibit colour shading. The vignetting produced by each camera tube is conventionally compensated by multiplying a correction signal by the camera tube output. The correction signal is usually of a simple parabolic waveform and although the resulting correction is acceptable this conventional method is tedious and must be undetaken by a skilled techician.

A further embodiment of the present invention provides apparatus for correcting image vignetting comprising monitoring means for monitoring the signals from each of a plurality of picture elements, processing means for calculating a correction signal from the monitored signals and control means for applying the correction signal to correct vignetting of images.

Similarly, an associated aspect of the present invention provides a method of correcting image vignetting comprising the steps of monitoring the

signals from each of a plurality of picture elements, calculating a correction signal from the monitored signals and applying the correction signal to correct vignetting of images.

It is known that even in the presence of only bias lighting the image produced by a camera tube exhibits shading. Bias lighting is provided for a camera tube so as to reduce lag when the camera tube image changes. The bias lighting does not correspond to flat field illumination and it is therefore necessary to correct the output of the camera tube to avoid shading in the final image.

Conventionally, such correction is achieved by the addition of parabolic and sawtooth waveforms to the output of the camera tube. However, this is tedious and may fail to provide complete correction.

A further preferred embodiment of the invention therefor provides apparatus for correcting image black shading comprising monitoring means for monitoring the signals produced by bias lighting from each of a plurality of pictures elements, comparator means for comparing each monitored signal with a reference to provide an error value for each picture element, processing means for calculating a correction signal

from the error values and control means for applying the correction signal to correct images.

In a corresponding embodiment the present invention there is provided a method of correcting black shading comprising the steps of monitoring the signals produced by bias lighting from each of a plurality of picture elements, comparing each monitored signal with a reference to provide an error value for each picture element, calculating a correction signal from the error values and applying the correction signal to correct images.

Errors are introduced into the image produced by a television camera tube due to geometric phenomena of the camera. The errors can be caused by the geometry of the camera tube and/or scanner yoke iself. Further errors can be introduced by non-linearities of image scanning within the camera tube. Such errors in general are more prevalent towards the edges of the image. Geometric errors can be caused by non-linearities of scanning yoke current wave forms and by pin cushion or barrel distortion in image scanning.

Conventionally, electrical input to the camera tube yoke has been varied manually so as to obtain the most acceptable final image. This requires a skilled

operator, is tedious and often does not provide optimum results.

In a further preferred embodiment of the present invention there is provided image correction apparatus for correcting errors in the image produced by an electro-optical tube due to geometric phenomena comprising monitor means for monitoring the value of a parameter from each of a plurality of picture elements, processing means for calculating a correction signal from the parameter values and control means for applying the correction signal to correct images produced by the electro-optical tube.

Similarly, a further preferred embodiment of the present invention provides a method of correcting errors in the image produced by an electro-optical tube due to geometric phenomena comprising the steps of monitoring the valve of a parameter from each of a plurality of picture elements calculating a correction signal from the parameter values and applying the correction signal to correct images produced by the electro-optical tube.

The optical arrangement of a camera lens can introduce defects in an image produced by a camera tube. Such defects are a particular problem in situations where the focal length of the camera lens is

varied, either by changing lenses or by the use of zoom lenses. Zoom lenses used with television broadcast cameras can establish focal length ratios of up to 42:1. Such dramatic changes in focal length are, of course, accompanied by equally dramatic changes in the angle of view and such changes in the angle of view can severely aggravate defects in the image produced by the camera tube. Lateral chromatic abberation defects which vary with focal length also present an important problem to be solved.

Another embodiment of the present invention provides apparatus for correcting camera lens produced defects in an image produced by a camera tube comprising monitoring means for monitoring a parameter value for each of a plurality of picture elements, processing means for calculating a correction signal from the parameter values, control means for applying the correction signal to correct image defects and scaling means for scaling the correction signal in accordance with variations of focal length of the camera lens.

Advantageously, in each embodiment, calculation of the correction signal involves a feedback configuration. A first correction is applied and its effect monitored. The correction is adjusted, if necessary, and a repetitive sequence undertaken until

the optimum correction is obtained.

An associated embodiment consists of a method of correcting camera lens produced defects in an image produced by a camera tube comprising monitoring a parameter valve for each of a plurality of picture elements, calculating a correction signal from the parameter values, applying the correction signal to correct image defects and scaling the correction signal in accordance with variations of focal length of the camera lens.

Preferably, in each embodiment of the present invention calculation of the correction signal includes multiplying each of two adjacent picture element error signals by a respective reference signal, the reference signals being in anti-phase with each other and being equal in frequency to half the frequency of occurrence of the picture elements whose error signals are being multiplied and summing the multiplied signals, whereby calculation of the correction signal includes a smoothed interpolation.

This smoothed interpolation can advantageously be realised using the scaling characteristics of digital to analog converters.

Embodiments of the present invention will now be described by way of example only and with reference to the accompanying drawings, in which:-

Figure 1 is a diagrammatic representation of the interpolation of different signals,

Figure 2 is a block diagram of a circuit for implementing the interpolation illustrated by figure 1,

Figure 3 is a block diagram showing a focus correction apparatus,

Figure 4 illustrates the spatial registration of a picture element signal compared with a reference picture element,

Figure 5 illustrates a desired camera tube signal output, the actual output and the correction signal required to produce the desired output,

Figure 6 is a block diagram of part of the apparatus for correcting camera tube vignetting,

Figure 7 is a block diagram showing the circuit of figure 2 with an attenuator connected to the output, and

Figure 8 is a graph illustrating percentage change in geometry as a function of camera lens focal length.

In a television camera there are many features of the image produced which deviate from the ideal arrangement. Often the deviation results in a picture image of unacceptably poor quality. Automatic correction of such deviation may be provided by this invention.

The particular feature of the image to be corrected is selected. The correction apparatus is set so as to measure the relevant correction parameter value. The correction parameter value is then measured from each of a plurality of picture elements. The precise method of measuring the correction parameter value depends upon the correction being made, but will usually include comparison of a signal from each picture element with a respective reference signal.

Many features of the television camera will require a correction relating to precise elements of an image as viewed through the optical system of the camera. In such cases a test chart is located in front of the camera. The test chart contains a regular matrix of 15 rows and 15 columns of rectangular picture areas. The picture areas are identical and are simply areas of small white rectangles on a black background.

The value of the relevant parameter is measured from the signal produced by each of the picture areas on the test card. The measured values are converted to digital form in order to facilitate subsequent processing.

A circuit for monitoring valves from the picture elements may include gate location of the individual picture elements, analogue processing of the gated

video, analogue to digital conversion and storage in a RAM under the control of a CPU. The RAM stored values can be interpolated in real time to provide a correction signal which is applied for real time correction of the image defects.

A correction signal is calculated from the correction parameter values. In calculating the required correction signal it is necessary to process line and field data simultaneously.

Typically, the line rate is of the order of 10's of KHz and the field rate seldom exceeds a few hundred hertz. Low pass filtering is possible for line data but is not simultaneously possible for field data since such filtering would result in the loss of information from the line data. It is therefore necessary to use an interpolation technique.

Conventional interpolation techniques used in data processing utilise complex software. Such software can be expensive, difficult to maintain and will sometimes produce discontinuities in interpolation which would result in an unacceptable positional change in the image.

Interpolation of the correction parameter values in can be implemented utilizing the scaling function of

digital to analog converters. Other interpolation techniques may be used.

Each correction parameter value, in digital form, from a pair of adjacent field data picture elements is multiplied by a respective reference signal. The reference signals have a frequency equal to half the frequency of occurrence of field picture elements and the reference signals are in anti-phase with each other. The multiplied values are summed and thereby provide a smoothed interpolation.

Figure 1 illustrates the field rate interpolation of information. Two reference signals are provided, V REF.1 and V REF.2. The frequency of the reference signals is half the frequency of occurance of the picture elements whose valves are being multiplied. V REF.1 and V REF.2 vary, in this example, linearly between maxima and minima and are in anti-phase with each other.

Interpolation between two adjacent field correction parameter values, value 1 and value 2, will now be considered. The reference signals vary between a minimum of 0 and a maximum of V. The first correction parameter value, value 1, is multiplied by V REF.1 and the second correction parameter value, value 2, is

multiplied by V REF.2. Initially, V REF.1 has a value of V and V.ef.2 has a value of O. At time A in Figure 1 the sum of the correction parameter values multiplied by the respective reference signals is therefore V x value 1. Interpolating between value 1 and value 2, V REF.1 decreases to 0 while V REF.2 increases to V. Consequently, when the interpolation is mid-way between the two values the situation will be as depicted by time B in Figure 1. Namely, the output signal will be equal to V/2 X (value 1 + value 2). Having completely traversed from the first picture element to the second picture element, the signals will be as depicted at time C in Figure 1. The output signal is now equal to V x value 2. The process is then repeated between value 2 and the next value, value 3. The temporal position of value 3 is represented by D in Figure 1.

A circuit for implementing the interpolation illustrated by Figure 1 is shown in Figure 2. The interpolation utilises the scaling function of digital to analog converters. Two digital to analog converters 2 and 4 are provided. V REF.1 is applied to an input of the converter 2 and V REF.2 is applied to an input the converter 4. Initially, value 1 is applied to an input of converter 2 and value 2 is applied to an input of converter 4. Outputs from the converters 2 and 4 are applied to a summing circuit 6. The value applied to

each digital to analog converter 2 and 4 is changed when he respective reference signal, V REF.1 or V REF.2, reaches 0. Consequently, referring to Figure 1, at time C the value applied to converter 2 is changed from value 1 to value 3. Similarly, at time D the value applied to converter 4 is changed from value 2 to value 4 the fourther correction parameter value.

In the vertical direction interpolation is achieved by mixing the outputs of two multiplying D/A convertors. D/A 1 carries the values corresponding to row 1 of samples, while D/A 2 has the values for row 2. As the scan progresses down the picture the output from D/A 1 is reduced while the output from D/A 2 is increased. This produces a crossfade between the two convertor outputs thus providing vertical interpolation. When row 2 has been reached D/A 1 is loaded with the correction data for row 3 and the corssfade procedure is repeated with D/A 2 output decreasing as D/A 1 output increases. The effect of samples more than one row apart on the final analogue waveform is taken care of by iterative correction routines as described later. To cope with the waveforms required at the edges and the corners of the picute, offscreen software routines have been developed to interpolate into the blanking areas. Interpolation between sample areas in the horizontal direction, is

achieved by filtering the analogue output of the D/A outputs.

Application of the above described technique to the correction of focus related errors will now be considered.

A test chart consisting of a matrix of fifteen rows and fifteen columns of identical rectangular white areas on a black background is provided for use in focus correction.

Focus correction is carried out for each individual camera tube of which there may be a number, for example in a colour television broadcast camera.

The focussing of a camera tube requires correction due to the fact that the camera tube image provides a uniform focus for a curved object plane. This defect is produced by well known phenomena and obviously requires correction. Conventionally, a predetermined correction signal has been applied to the camera tube electrostatic field, but such correction signals have been determined from theoretical considerations or by the trial and error application of correction signals. This invention provides a correction signal which is calculated from the optimum focus parameter value at each of a plurality

of picture elements.

A camera tube is manually focussed on the test chart. A picture element signal is produced by the camera tube and is applied to the focus correction apparatus 10 shown in Figure 3.

The focus correction apparatus 10 comprises monitoring means 12 for measuring the optimum focus parameter value at each of the picture elements, processing means 14 for calculating a correction signal from the measured values and control means 16 for applying the correction signal to correct the electon beam focussing of the camera tube image.

The camera tube image signal is passed to the input 18 of the measuring circuit 12. The circuit 12 includes a gate circuit 20 which is responsive to the video signal of the picture element viewed by the camera and thus the picture area provided by the test chart. Gate location of the picture element with the picture area is undertaken prior to the initiation of the measuring sequence. The gated video signal is passed from the gate unit 20 to a band pass unit 22. The band pass unit 22 filters the picture element signal so that only the high frequency energy, presented in the video information of the picture area under investigation, is

used for further processing. The filtered picture element signal is passed to a peak detector 24. The peak detector 24 detects the peak-to-peak amplitude of the filtered picture element signal. A sample and hold unit 26 receives peak-to-peak amplitude data from detector 24 and the units 20 to 26 constitute the measuring circuit 12.

Subsequent to gate 20 identifying registration of the camera tube picture element with a test chart picture area, the voltage applied to the tube focussing electrode 28, is increased in steps over a preset range of voltages. For each focussing electrode voltage the peak-to-peak amplitude is detected by the detector 24 and is passed to the sample and hold unit 26 and thus to the CPU which retains a record of which of the focus electrode voltages resulted in the maximum peak-to-peak amplitude of the picture element signal. Having determined and retained a record of the focus, the gate control is progressed so as to coincide with the next picture area of the test chart, until all the 225 locations or areas are tested. The values for focus are then compared to a previous pass and a correction is output to increase the focus at each location. The process is repeated until optimum focus is achieved in all locations.

The processing means 14 includes an analog to digital converter 30, a CPU 32, a RAM 34 and a digital to analog converter 36. The signal passed from the sample and hold unit 26 of the measuring circuit 12 is in analog form. That signal is converted by the analog to digital converter 30 and the digital information is stored in the RAM 34 under the control of the CPU.32. Under control of the CPU 32 the RAM 34 stores information relating to the signal received from each of the picture elements. When the measuring operation has been completed for all of the picture elements of the camera tube the RAM 34 in effect stores the correction signal necessary to compensate the camera tube image so as to simulate a flat object plane of uniform focus.

The real time application of the correction values stored in the RAM 34 to the focussing electrode voltage is inconvenient. Consequently, it is necessary to provide an interpolation of the value storage in RAM 34 in order to effect real time correction of the focussing electrode voltage. The digital-to-analog unit 36 is used to provide a smoothed interpolation in the manner described above with reference to Figures 1 and 2. The signal derived from interpolation by unit 36 is applied to the modulator 16 which is interposed between the focus voltage supply 38 and the focussing electrode 28. Unit 36 modulates the supplied focus voltage in

accordance with the interpolated signal from unit 36 so that the voltage received by the focussing electrode 28 is fully corrected, whereby optimum focussing of the camera tube image is provided.

Interpolation of the value stored in RAM 34 utilises the scaling function of digital to analog converters. The values from two adjacent picture elements are each multiplied by a respective reference signal and the multiplied values are summed. Multiplication of the values from RAM 34 is undertaken in the manner explained with the aid of Figure 1. The interpolation is effected by the circuitry shown in Figure 2 which corresponds to the digital to analog unit 36 of Figure 3.

In a colour television camera it is necessary to ensure common registration of all of the camera tubes in order to avoid imperfections in the final television image. This is achieved by the projection of a test chart within the prism system of the camera. Registration of each of the tubes is measured against the test chart and a correction signal is calculated for each camera tube and applied so as to correct the output thereof.

The test chart consists of a regular matrix of fifteen rows and fifteen columns of identical

rectangular white areas on a black background. Each of the white area acts as a reference picture element.

A correction signal is provided for each of the camera tubes and since the process is the same for each tube a detailed description will be given with respect to one tube only.

The image produced by the camera tube is divided into 225 picture elements each of which should be in registration with a respective picture area of the test chart. For each of the picture elements in turn, the picture element signal is measured and is compared with the reference picture element. It will be appreciated that the reference picture elements are provided by the output of the reference tube, usually the green channel.

An error signal is generated corresponding to the error of registration between the picture element signal and the reference picture element. Figure 4 illustrates variation of the error signal 40.

The above procedure is repeated for all of the 225 picture elements. Subsequently, a correction signal is calculated for the camera tube by interpolation of the picture element error values.

A circuit for monitoring values from the picture elements may include gate location of the individual picture elements, registration error detector, analogue to digital conversion and storage in a RAM under the control of a CPU. The RAM stored values can be interpolated in real time to provide a correction signal which is applied for real time correction of the image defects.

Conventional interpolation techniques used in data processing utilise complex software. Such software can be expensive, difficult to maintain and will sometimes produce discontinuities in interpolation which would result in unacceptable postional changes in the final television image. Interpolation of the picture element error values in this embodiment of the present invention may utilise the scaling function of digital to analogue converters. Such an interpolation is described above with reference to Figures 1 and 2 of the drawings.

In a colour television camera it is particularly necessary to correct vignetting produced by the individual camera tubes in order to avoid colour shading being exhibited by the final image. The vignetting produced by the three colour camera tubes is unique for each colour.

A software generated flat field reference is compared with the actual video signal from each camera tube and the required correction signal for that tube is calculated. The correction signal is then applied to the output of the camera tube so that all images produced by the tube are corrected for vignetting.

A circuit for monitoring values from the picture elements may include gate location of the individual picture elements, sample and hold of the video level, analogue to digital conversion and storage in a RAM under the control of a CPU. The RAM stored valves can be interpolated in real time to provide a correction signal which is applied for real time correction of the image defects.

Figure 5 illustrates the vignetting of a camera tube image and illustrates the required correction signal. The uncorrected image produced by a camera tube is represented by the line 50 which is curvilinear as opposed to the linear desired output 52. The curvilinear form of signal 50 is manifest as a darkening towards the edge of the image. This is the common phenomenon of vignetting which along with some tube and prism defects is also referred to in respect of colour television cameras as black and white shading. It will be appreciated from Figure 5 that a correction signal

illustrated by the phantom line 54 must be added to the camera tube signal 50 so as to produce the desired output signal 52. The correction signal 14 is the complement of the signal 50.

The correction signal 54 is provided in the following manner. The video signal is monitored for each of a pluraltiy of picture elements of the camera tube image. These picture element signals are each compared with a respective reference picture element signal forming part of the software generated flat field reference. Using the error values obtained from the comparison of each picture element with its reference, the correction signal 54 is calculated. A feedback configuration is sued and the correction signal calculated in a repetitive sequence until the comparison reveals no error.

For white shading, the picture element signals are provided by the diascope within the camera tube and an external image is not therefore required to generate the picture elements.

Separate detectors are used for looking at Black Shading performance and White Shading. To improve immunity to noise the Black Shading detector integrates the whole of the sample area and produces a dc level to

the A/D convertor which corresponds to the video level present at the location. As before multiple passes the picture are made with the analogue correction waveform being updated and applied to the video processing amplifier before the sample point, thus the effect of the correction will be monitored on succesive passes. This iterative process enables the generated correction waveform to evolve step by step, until the correction waveform exactly offsets the black shading present. In this way black shading can be corrected to better than 0.5% of peak white, both absolutely and differentially, as measured after Gamma correction.

To measure White Shading errors the diascope pattern is again used and the video level measured by a peak detector. This dc level is A/D converted for use by a Microprocessor. Again multiple passes are used with the correction waveform steadily developing until an exact fit is obtained to the nearest increment of the value stored in memory. White Shading errors can be reduced to less than 1% after Gamma correction both absolutely and differentially by the technique. To overcome any deficiencies in the eveness of illumination of the diascope the camera has a routine to allow the difference between an externally illuminated flat field as seen through the lens and the diascope field to be stored and used to modify the results subsequently

obtained with the diascope.

A simplified block diagram is given in Figure 6 in order to illustrate the apparatus for monitoring the picture element signals and calculating the correction signal. The video signal from each picture element is applied in turn to the input 60. Each video signal is processed by a sample and hold unit 62 and subsequently passed to an analog to digital converter 64. The digital signals are passed to a CPU 66 under the control of which they are stored in a RAM 68. The values stored in the RAM 68 are interpolated so as to form the correction signal 54. Interpolation is undertaken using the scaling function of digital to analog converter in a digital to analog unit 70.

The interpolation includes multiplying error values, in digital form, from each of two adjacent picture elements by respective reference signals. The multiplied values are summed and a smoothed interpolation is provided. The unit 70 is formed of the circuit of Figure 2 and the interpolation is carried out as described with reference to Figures 1 and 2.

In the black shading case, the camera tubes of a colour television camera are supplied with bias lighting which reduces the lag which the tubes would otherwise

exhibit in responding to the change in images viewed by the camera. However, the bias lighting does not represent a flat field and will consequently introduce shading in the final image unless correction is undertaken.

The colour television camera is set for operation but the lens cap is retained on the camera lens. Consequently, only the bias lighting is available for producing an output signal from the camera tubes. For each of the tubes a correction value is calculated to compensate for the fact that the bias lighting does not present a flat field. These correction signals are stored and applied to the output from the camera tubes during normal operation of the camera, so as to avoid shading in the final image being caused by the bais lighting. Only bias lighting is required within the camera and any diascope is switched off.

A circuit for monitoring values from the picture elements may include gate location of the individual picture elements, sample and hold of the video level, analogue to digital conversion and storage in a RAM under the control of a CPU. The RAM stored values can be interpolated in real time to provide a correction signal which is applied for real time correction of the image defects.

The calculation of a correction signal for one camera tube will now be described.

The correction of camera tube black shading comprises monitoring the signals produced by the bias lighting from each of a plurality of picture elements, comparing each monitored signal with a reference to provide an error value for each picture element, calculation of a correction signal from the error values and application of the correction signal so as to correct images produced by the camera tube. A feedback configuration is used in a repetitive sequence until no error is detected by the comparison.

The reference is software generated and interpolation is necessary in calculating the correction signal.

Coventional interpolation techniques used in data processing utilise complex software. Such software can be expensive, difficult to maintain and will sometimes produce discontinuities in interpolation.

Interpolation of the error values in this embodiment of the invention can utlise the scaling function of digital to analog converters. Such an interpolation is described above with reference to Figures 1 and 2.

Errors are introduced into the image produced by a television camera tube due geometric phenomena of the camera. Such phenomena include geometry of the camera tube itself and non-linearities of image scanning within the camera tube. Automatic correction of such errors may be provided by this invention.

Image correction is achieved by monitoring picture element signals from an object, generating elemental signals of the desired image, comparing corresponding picture element and elemental signals, calculating a correction signal from said comparison and applying the correction signal to correct images produced by the camera tube.

A test chart containing a regular matrix of fifteen rows and fifteen columns of rectangular picture areas is located in front of the camera. The picture areas are identical and are simply rectangular areas of white on a black back ground.

Geometric correction may normally be considered to

be the registration of green video to an electronic reference. The picture elements are then scanned and the signal from each picture element is stored for processing. It should be appreciated that these stored values will include accumulative errors caused by the various geometric phenomena produced within the camera.

A circuit for monitoring valves from the picture elements may include gate location of the individual picture elements, geometry/registration detection, analogue to digital conversion and storage in a RAM under the control of a CPU. The RAM stored values can be interpolated in real time to provide a correction signal which is applied for real time correction of the image defects.

A reference generator generates elemental signals of the desired image which is, of course , an exact replica of the test chart. Corresponding picture element and elemental signals are compared by a comparator which generates a difference signal for each of the picture elements.

The difference signals represent the accumulative geometric errors.

A correction signal is calculated from the difference signals and is applied so as to correct images produced by the camera tube. A feedback configuration is used in a repetitive sequence until a minimum error is measured for all areas. Calculation of the correction signal is undertaken by processing means which utilise interpolation between adjacent difference signals. Control means are provided for storing the correction signal and applying the correction signal so as to correct images produced during normal operation of the camera tube.

Interpolation of the difference signals by the processing means utilises the scaling function of digital to analog converters. Difference values from adjacent picture elements are multiplied by a respective reference signal and the multiplied values are summed. The interpolation used is that described above with reference to Figures 1 and 2 of the drawings. The measurement and correction techniques are the same for both geometry and registration errors. The output of the green channel and an electronically generated version of the test pattern, which is taken as the reference, are compared location by location, first for vertical error detection and correction and then for horizontal detection and correction. The reference itself is switched through the detectors such that any

errors in the detectors will be automatically compensated for.

Errors are detected by addressing the detector to each location in turn and determining what polarity of correction is required. Starting from a mid point value, the memory location for each sample is then incremented or decremented according to the sense of correction required. After each complete pass of the test pattern the memory values are read out and converted to an analogue waveform as previously described and applied to all three scan amplifiers to modify the scanning current waveforms. The procedure is then repeated until all locations are corrected to less than one increment of accuracy. To speed up the process the size of correction increments is large for the early passes and reduced as the routine proceeds. By this method the geometry of the green channel can be corrected to better than 0.1%. This figure of course excludes the lens geometry.

The same routine is used for correction registration errors, except the reference is now the green channel, instead of the electronic reference and the correction waveform is applied to the Red or Blue scan amplifiers only, as appropriate. Registration to better than 0.05% of picture ehight, over the entire picture area is

achieved using this method. To cope with the differences between the registration obtained using the diascope and that prodduced by the lens, the camera has a routine to enable it to "learn" the difference in errors. Having registered with the diascope, the camera is pointed at an optical chart having the same pattern as the diascope slide. The optimum distance between lens and chart is used, as specified by the lens manufacturer. The automatic routine is then repeated to register the camera under these conditions. The difference between the two sets of correction data is stored as a correction factor, which is then used to modify all subsequent line ups from the diascope. Correction factors for several lens types can be held in memory at the same time, as a coding system is used to enable the camera to recognise which type of lens is in current use.

The optical arrangement of a camera lens can introduce defects in the image produced by a camera tube. Such defects are particularly problematic where the focal length of the lens is varied, either by changing the lens or by using a zoom lens. In a colour televison camera a zoom lens may have a focal length ratio of 42:1. Such drastic changes in focal length are, of course, accompanied by equally drastic changes in the field of view. Such changes severely aggravate

the defects introduced into the camera tube image. Lateral chromatic abberation is also a particularly important problem for colour television broadcast cameras utilising zoom lenses of high focal length ratios.

These disadvantages are mitigated by producing a correction signal for correcting camera lens produced defects which are present in the camera tube image and by scaling the scanning amplitudes relative to the focal length of the lens. This form of compensation is particularly effective and relatively simple because the correction signal can be scaled essentially linearly with the focal length of the lens. The lens geometry changes particularly dramatically for wide angle setting and this is illustrated by the graph of Figure 7.

In order to generate the correction signal the image signal from each of a plurality of picture elements is measured. The picture element signals are each compared with a single or respective elemental reference so as to provide an error value for each picture element. The error values are stored in digital form and are interpolated to provide the correction signal. The picture elements may be generated by positioning a test chart in front of the camera. The test chart contains a regular matrix of fifteen rows and fifteen columns of

identical rectangular areas of white shading on a black background.

A circuit for monitoring values from the picture elements may include gate location of the individual picture elements, geometry/registration detection, analogue to digital conversion and storage in a RAM under the control of a CPU. The RAM stored values can be interpolated in real time to provide a correction signal which is applied for real time correction of the image defects.

Conventional interpolation techniques used in data processing utilise complex software. Such software can be expensive, difficult to maintain and will sometimes produce discontinuities in interpolation.

Interpolation of the error values in this embodiment of the present invention can utilise the scaling function of digital to analog converters. Such an interpolation is described above with reference to Figures 1 and 2 of the drawings.

It will be appreciated that in each of the above embodiments automatic image of the above embodiments automatic image correction is provided. Such correction may, in each case, use a feedback configuration whereby

a correction is obtained, its effect monitored and repetitive adjustment undertaken until the optimum result is obtained.

Several embodiments of the present invention have been described above but it will be evident to those skilled in the art that many variations are possible without departing from the scope of the invention. For example, in some circumstances it may be advantageous for the reference signals V REF.1 and V REF.2 to have a non-linear form.

CLAIMS

1. Apparatus (10) for correcting defects in an image having a plurality of picture elements, characterised by monitoring means (12) for measuring the value of a parameter from each of the picture elements, processing means (14) for calculating a correction signal from the parameter values and control means (16) for applying the correction signal to correct the image defects.

2. Focus correction apparatus (10) for an electro-optical tube characterised by monitoring means (12) for measuring the optimum focus parameter value at each of a plurality of picture elements, processing means (14) for calculating a correction signal from the measured values and control means (16) for applying the correction signal to correct the focussing of images produced by the electro-optical tube.

3. Apparatus (10) as claimed in claim 2, characterised in that the means (12) for measuring includes means for testing the focus parameter value, for each picture element, over a preset range of focussing control values and means (24) for identifying the focussing control values, for each picture element, which results in the maximum focus parameter value amplitude, the identified control value representing the optimum focus for the picture element.

4. Apparatus as claimed in claim 3, characterised by a band pass filter (22) for filtering picture element signals such that only high frequency energy of the picture element signal is passed to the identifying means (24).

5. Apparatus as claimed in claim 3 or 4, characterised in that the identifying means (24) includes a peak-to-peak detector which detects the focus parameter value amplitude.

6. Apparatus for calculating relatively small spatial registration errors of an elector-optical tube characterised by a reference generator which generates a plurality of reference picture elements, monitoring means which monitor the picture element signals of the tube dervied from said reference picture elements, comparator means which compare picture element and reference picture elements signals, displacement means which, for each picture element, displaces the picture element in a first direction to a position (A) of relatively large registration error, as measured by the comparator means, and which displaces the picture elements in a direction opposite the first direction to a position (C2) of substantially the same relatively large registration error, as measured by the comparator means, and processing means for calculating, from the

displacements effected by the displacement means, the position of optimum spatial registration and an error signal representing the initial error in spatial registration of the picture element.

7. Apparatus for compensating spatial registration errors of a camera tube including the apparatus of claim 6 and further characterised by additional processing means for calculating a correction signal from the calculated picture element error signals and control means for applying the correction signal to compensate images produced by the camera tube for errors in spatial registration of the tube.

8. Apparatus for correcting image vignetting characterised by monitoring means (62) for monitoring the signals from each of a plurality of picture elements, processing means (64-70) for calculating a correction signal (54) from the monitored signals and control means for applying the correction signal (54) to correct vignetting of images.

9. Apparatus as claimed in claim 8, characterised in that the picture elements are generated by a diascope within a camera tube.

10. Apparatus for correcting image black shading characterised by monitoring means for monitoring the signals produced by bias lighting from each of a plurality of picture elements, comparator means for comparing each monitored signal with a reference to provide an error value for each picture element, processing means for calculating a correction signal from the error values and control means for applying the control signal to correct images.

11. Image correction apparatus for correcting errors in the image produced by an electro-optical tube due to geometric phenomena, characterished by monitor means for monitoring the valve of a parameter from each of a plurality of picture elements, processing means for calculating a correction signal from the parameter valves and control means for applying the correction signal to correct images produced by the electro-optical tube.

12. Apparatus for correcting camera lens produced defects in an image produced by a camera tube, characterised by monitoring means for monitoring a parameter valve for each of a plurality of picture elements, processing means for calculating a correction signal from the parameter values, control means for applying the correction signal to correct image defects and

scaling means for scaling the correction signal in accordance with variations of the focal length of camera lens.

13. Apparatus as claimed in claim 12, characterised in that the scaling means scales the correction signal linearly in accordance with variations of the focal length of the camera lens.

14. Apparatus as claimed in any preceding claim, characterised by the processing means including means for undertaking a repetitive feedback technique in calculation of the correction signal.

15. Apparatus as claimed in any preceding claim, characterised in that the processing means comprises two multipliers (2, 4) each of which multiplies one of two adjacent line or field parameter values (VALUE 1, VALUE 2) by a respective reference signal (V.REF 1, V.REF 2) which has a frequency equal to half the frequency of occurrence of the picture elements whose values are being multiplied, the reference signals (V.REF 1, V.REF 2) being in anti-phase with each other, and a summing circuit (6) for summing the multiplied values, whereby calculation of the correction signal includes a smoothed interpolation.

16. Apparatus as claimed in claim 15, characterised in that the parameter values are in digital form and each multiplier (2, 4) comprises a digital to analog converter.

17. Apparatus as claimed in claim 15 or 16, wherein the reference signals are linear between maxima and minima.

18. Apparatus as claimed in any of claims 1 to 7 or 10 to 17, further characterised by a test chart having a regular matrix of identical picture areas, the picture areas providing respective image elements for the picture elements.

19. A television camera characterised by the apparatus of any preceding claim.

20. A method of correcting defects in an image having a plurality of picture elements, characerised by measuring the value of a parameter at each of the plurality of picture elements, calculating a correction signal from the parameter values and applying the correction signal to correct image defects.

21. A method of focus correction for an electro-optical tube,characterised by the steps of measuring the optimum focus parameter value at each of a plurality of picture

elements, calculating a correction signal from the measured values and applying the correction signal to correct the focussing of images produced by the electro-optical tube.

22. A method as claimed in claim 21, characterised by, for each of the picture elements, testing a preset range of focussing control values and identifying the control value which results in the maximum focus parameter value amplitude, the identified control value representing the optimum focus for the picture element.

23. A method as claimed in claim 22, characterised by the step of band pass filtering picture element signals such that high frequency energy of the picture element is used for identifying the maximum focus parameter value amplitude.

24. A method as claimed in claim 24, including the peak-to-peak detection of focus parameter value amplitude.

25. A method of calculting relatively small errors in the spatial registration of an electro-optical tube characterised by the steps of providing a plurality of reference picture elements, monitoring the picture element signals of the tube derived from said reference

picture elements, comparing picture element and reference picture element signals for each picture element, displacing the picture element in a first direction to a position of relatively large registration error, displacing the picture element in a direction opposite the first direction to a position of substantially the same relatively large registration error and calculating, from the displacements effected, the position of optimum spatial registration and an error signal representing the initial error in spatial registration of the picture element.

26. A method of compensating spatial registration errors of an electro-optical, characterised by the steps of the method of claim 25 and including calculating a correction signal from the calculated picture element error signals and applying the correction signal to compensate images produced by the tube for errors in spatial registration of the tube.

27. A method of correcting image vignetting, characterised by the steps of monitoring the signals from each of a plurality of picture elements, calculating a correction signal from the monitored signals and applying the correction signals to correct vignetting of images.

28.A method as claimed in claim 27, characterised by the provision of a diascope within the camera tube having a regular matrix of identical picture areas.

29. A method of correcting image black shading characterised by the steps of monitoring the signals produced by bias lighting from each of a plurality of picture elements, comparing each monitored signal with a reference to provide an error value for each picture element, calculating a correction signal from the error values and applying the correction signal to correct images.

30. A method of correcting errors in the image produced by an electro-optical tube due to geometric phenomena characterised by the steps of monitoring the valve of a parameter from each of a plurality of picture elements calculating a correction signal from the parameter valves and applying the correction signal to correct images produced by the electro-optical tube.

31. A method of correcting camera lens produced defects in an image produced by a camera tube, characterised by monitoring a parameter valve for each of a plurality of picture elements, calculating a correction signal from the parameter values, applying the correction signal to correct image defects, and scaling the correction signal

in accordance with variations of the focal length of the camera lens.

32. A method as claimed in claim 31, characterised by scaling the correction signal linearly in accordance with variations of the focal length of the camera lens.

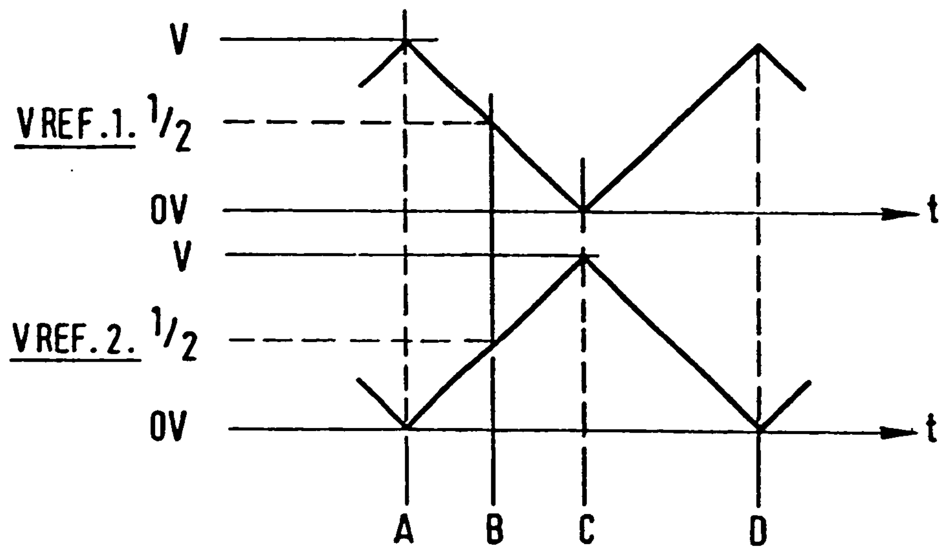
33. A method as claimed in any of claims 20 to 32, characterised by undertaking a repetitive feedback technique in calculation of the correction signal.

34. A method as claimed in any of claims 20 to 33, characterised in that calculation of the correction signal includes multiplying each of two adjacent line or field parameter values by a respective reference signal which has a frequency equal to half the frequency of occurrence of the picture elements whose valves are being multiplied, the reference signals being in anti-phase with each other, and summing the multiplied values, whereby the calculation includes a smoothed interpolation.

35. A method as claimed in claim 34, characterised by multiplying the parameter values, in digital form, and reference signals together in respective digital to analog converters.

36. A method as claimed in claim 34 or 35, characterised by selecting the reference signals to be linear between maxima and minima.

37. A method as claimed in any of claims 20 to 26 or 30 to 36, characterised by the provision of a test chart containing a regular matrix of identical picture areas and arranging the test chart such that the picture areas present a image element for respective picture elements.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t
V
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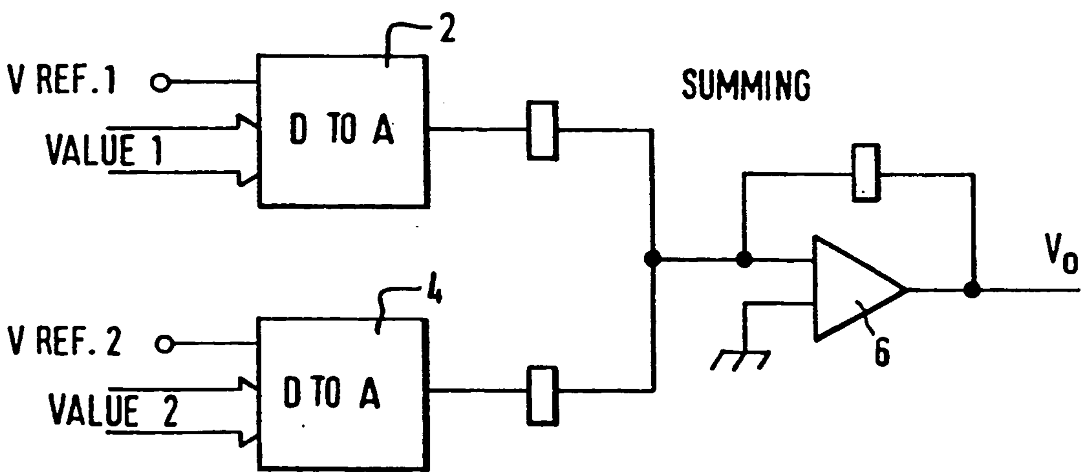
0V
t
A
B
C
D

FIG.1.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2
SUMMING
V REF.2
VALUE 2
D TO A
4
6
V_o

FIG.2.

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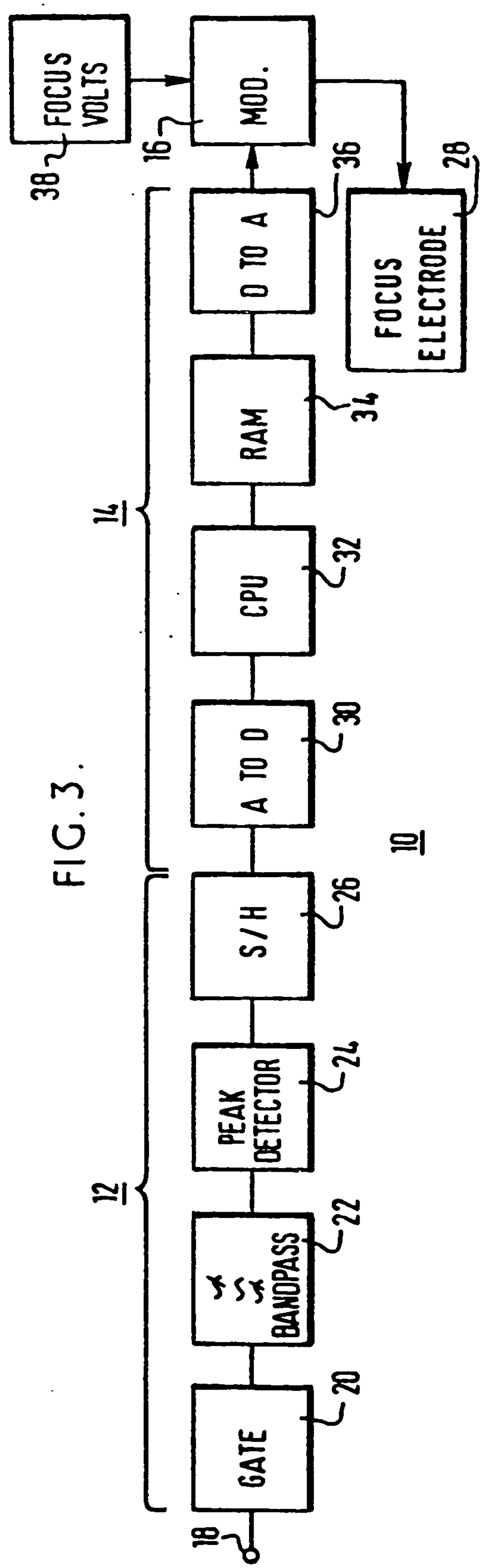

FIG. 3.

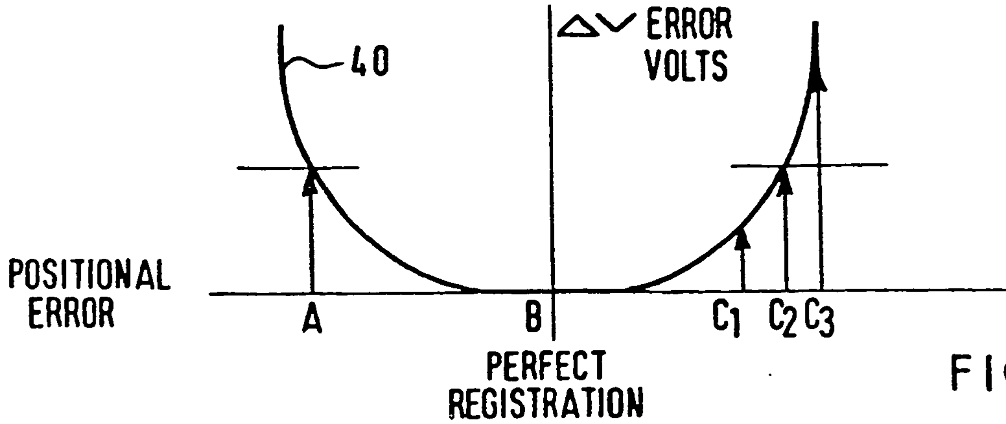

FIG. 4.

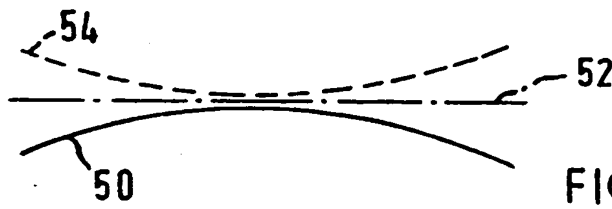

FIG. 5.

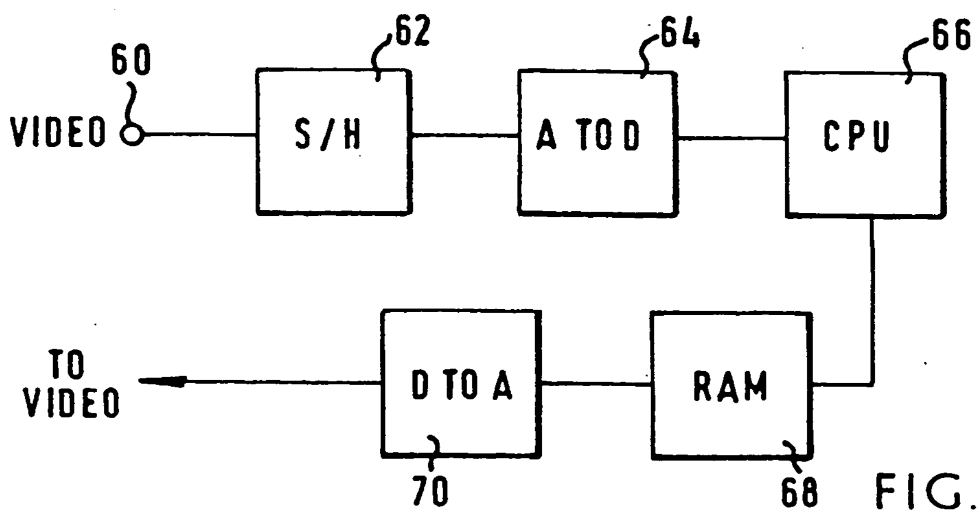

FIG. 6.

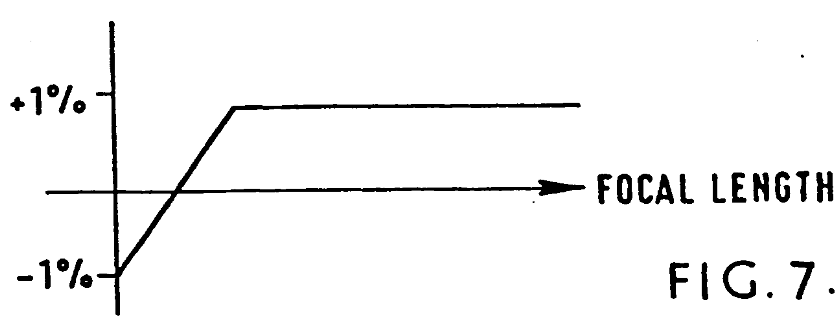

FIG. 7.

0104019

European Patent Office

EUROPEAN SEARCH REPORT

Application number

EP 83305156.8

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)
A	PHILIPS TECHNISCHE RUNDSCHAU, vol. 38, no. 11/12, 1979, Eindhoven A. HOYER, M. SCHLINDWEIN "Bildverbesserung durch digitale Nachverarbeitung" pages 311-323 * Page 311, fig. 1, columns 1,2 *		H 04 N 5/22 H 04 N 9/09
A	DE - A1 - 2 636 209 (HUGHES AIRCRAFT) * Page 31, claim 1 *		
A	DE - A1 - 3 114 888 (AMPEX) * Abstract; page 6, paragraph 1 - page 8, paragraph 1 *		TECHNICAL FIELDS SEARCHED (Int. Cl. 3)
A	DE - A1 - 3 107 042 (AMPEX) * Abstract; page 21, line 8 - page 27, line 11; claims 1,28 *		H 04 N 5/00 H 04 N 9/00
A	US - A - 4 320 414 (MIYAJI) * Abstract *		

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
VIENNA	15-12-1983	BENISCHKA

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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